

CLAIMS

What is claimed is:

1. A method in a wireless communication system comprising:

providing a downlink channel for transmitting downlink data from a first communication device having a smart antenna system to a remote communication device;

providing an associated channel for the first communication device to receive an uplink response signal from the remote communication device in response to the downlink data, the associated channel associated, and having a predefined relationship, with the downlink channel;

providing an uplink data channel for the first communication device to receive uplink data signal from the remote communication device, the uplink data channel distinct from the associated channel;

receiving the uplink response signal at the first communication device;

determining a downlink smart antenna processing strategy using the received uplink response signal;

sending downlink data from the first communication device to the remote communication device using the determined downlink smart antenna processing strategy; and

receiving uplink data from the remote communication device on the uplink data channel.

2. A method as described in claim 1, wherein the first communication device includes a base station, the remote communication device includes a user terminal associated with the base station and capable of communicating on the uplink and downlink with the base station, the smart antenna system includes a plurality of antenna elements, the downlink channel is a downlink traffic channel for communicating downlink traffic data, the sending of the uplink response signal is independent of any uplink traffic data being sent from the remote terminal to the base station, and the downlink smart antenna processing strategy of the sending downlink data step uses a recently received uplink response signal.
3. A method as described in claim 1, wherein the uplink data and downlink and uplink associated channels are conventional TDMA channels.
4. A method as described in claim 1, wherein the uplink data and downlink and uplink associated channels are conventional FDMA channels.
5. A method as described in claim 1, wherein the uplink data and downlink and uplink associated channels are conventional CDMA channels.
6. A method as described in claim 1, wherein the first communication device comprises a cellular base station.
7. A method as described in claim 1, wherein the remote communication device includes a second plurality of antenna elements.
8. A method as described in claim 7, wherein the remote communication device includes a second smart antenna system that includes the second plurality of antenna elements.
9. A method as described in claim 1, wherein the first communication device is coupled to an external data and/or voice network.
10. A method as described in claim 1, wherein the remote communication device includes a remote user terminal.
11. A method as described in claim 10, wherein the remote user terminal is mobile.

12. A method as described in claim 1, wherein at least one of the uplink and downlink data includes voice.
13. A method as described in claim 1, wherein at least one of the uplink and downlink data includes information exchanged via the Internet.
- 5 14. A method as described in claim 1, wherein the smart antenna system includes a plurality of antenna elements and a mechanism for uplink spatial processing signals received at the antenna elements according to a set of receive weighting parameters determined from the signals received at the antenna elements, and a mechanism for downlink spatial processing a signal for transmission according to a set of transmit weighting parameters, wherein the downlink
10 strategy determining includes determining the set of uplink weighting parameters from the uplink response signal received during the step of receiving the uplink response signal and determining the set of downlink weighting parameters from the set of uplink weighting parameters.
15. A method as described in claim 1, wherein communication on the downlink channel and on the associated channel is frame-by-frame, and wherein the downlink strategy determining step determines the strategy using the uplink response signal received in the most recent frame.
16. A method as described in claim 15, wherein the uplink response signal includes acknowledgement data sent by the remote communication device in response to each frame from the first communication device received by the remote communication device.
- 20 17. A method as described in claim 14, wherein the downlink strategy determining step determines the transmit weighting parameters using a blind method and the most recently received uplink response signal.
18. A method as described in claim 14, wherein the uplink response signal includes training data and wherein the downlink strategy determining step determines the transmit weighting
25 parameters using the training data in the most recently received uplink response signal.

19. A method as described in claim 15, wherein communications on the uplink and downlink channels and on the associated uplink channel are frame-by-frame, and wherein the uplink response signal includes acknowledgement data sent by the user terminal in response to each frame sent from the first communication device received by the remote communication device,
5 the method further comprising:

providing an associated downlink channel from the first communication device to the remote communication device, the associated downlink channel associated with and having a predefined relationship with the uplink channel;

10 sending an uplink acknowledgement signal from the first communication device to the remote communication device on the associated downlink channel in response to each uplink frame from the user terminal received by the first communication device.

20. A method as described in claim 1, wherein the remote communication device is a user terminal of a set of user terminals able to communicate with the first communication device, each user terminal able to communicate on the uplink on a distinct uplink channel of a set of provided uplink channels and on the downlink on a distinct downlink channel of a set of provided downlink channels, the total data carrying capacity of the set of provided downlink channels being greater than the total data carrying capacity of the set of provided uplink channels,
15 whereby the method accommodates the asymmetry between uplink and downlink traffic data communication.

21. A communication device comprising:

a smart antenna system to communicate with at least one remote communication device according to a smart antenna processing strategy, the smart antenna system including a plurality of antenna elements;

25 a downlink transmission unit, coupled to the antenna element plurality, to transmit downlink data on a downlink channel to the remote communication device;

an uplink reception unit, coupled to the antenna element plurality, to provide an associated channel to receive an uplink response signal from the remote communication device in response to the downlink data, the associated channel associated, and having a predefined relationship, with the downlink channel, the uplink reception unit further to provide an uplink data channel to receive an uplink data signal from the remote communication device, the uplink data channel being distinct from the associated channel; and

a processor, coupled to the downlink transmission unit, and further coupled to the uplink reception unit, the processor to determine a downlink smart antenna processing strategy based on the uplink response signal.

22. A communication device as described in claim 21, wherein the uplink data and downlink and uplink associated channels are conventional TDMA channels.
23. A communication device as described in claim 21, wherein the uplink data and downlink and uplink associated channels are conventional FDMA channels.
24. A communication device as described in claim 21, wherein the uplink data and downlink and uplink associated channels are conventional CDMA channels.
25. A communication device as described in claim 21, wherein the first communication device comprises a cellular base station.
26. A communication device as described in claim 21, wherein the remote communication device includes a second plurality of antenna elements.
27. A communication device as described in claim 26, wherein the remote communication device includes a second smart antenna system that includes the second plurality of antenna elements.
28. A communication device as described in claim 21, wherein the first communication device is coupled to an external data and/or voice network.
29. A communication device as described in claim 21, wherein the remote communication device includes a remote user terminal.

30. A communication device as described in claim 29, wherein the remote user terminal is mobile.
31. A communication device as described in claim 21, wherein at least one of the uplink and downlink data includes voice.
- 5 32. A communication device as described in claim 21, wherein at least one of the uplink and downlink data includes information exchanged via the Internet.
33. A machine-readable medium having stored thereon information representing a set of machine-executable instructions, that, when executed by a machine, cause the machine to perform a method comprising:

10 providing a downlink channel for transmitting downlink data from a first communication device having a smart antenna system to a remote communication device;

15 providing an associated channel for the first communication device to receive an uplink response signal from the remote communication device in response to the downlink data, the associated channel associated, and having a predefined relationship, with the downlink channel;

20 providing an uplink channel for the first communication device to receive uplink data signal from the remote communication device, the uplink channel distinct from the associated channel;

receiving the uplink response signal at the first communication device;

determining a downlink smart antenna processing strategy using the received uplink response signal;

25 sending downlink data from the first communication device to the remote communication device using the determined downlink smart antenna processing strategy; and

receiving uplink data from the remote communication device on the uplink data channel.

34. A machine-readable medium as described in claim 33, wherein the first communication device includes a base station, the remote communication device includes a user terminal associated with the base station and capable of communicating on the uplink and downlink with the base station, the smart antenna system includes a plurality of antenna elements and provides variable antenna patterns, the downlink channel is a downlink traffic channel for communicating downlink traffic data, the sending of the uplink response signal is independent of any uplink traffic data being sent from the remote terminal to the base station, and the downlink smart antenna processing strategy of the sending downlink data step uses a recently received uplink response signal.
35. A machine-readable medium as described in claim 33, wherein the uplink data and downlink and uplink associated channels are conventional TDMA channels.
36. A machine-readable medium as described in claim 33, wherein the uplink data and downlink and uplink associated channels are conventional FDMA channels.
37. A machine-readable medium as described in claim 33, wherein the uplink data and downlink and uplink associated channels are conventional CDMA channels.
38. A machine-readable medium as described in claim 33, wherein the first communication device comprises a cellular base station.
39. A machine-readable medium as described in claim 33, wherein the remote communication device includes a second plurality of antenna elements.
40. A machine-readable medium as described in claim 39, wherein the remote communication device includes a second smart antenna system that includes the second plurality of antenna elements.
41. A machine-readable medium as described in claim 33, wherein the first communication device is coupled to an external data and/or voice network.

42. A machine-readable medium as described in claim 33, wherein the remote communication device includes a remote user terminal.
43. A machine-readable medium as described in claim 42, wherein the remote user terminal is mobile.
- 5 44. A machine-readable medium as described in claim 33, wherein at least one of the uplink and downlink data includes voice.
45. A machine-readable medium as described in claim 33, wherein at least one of the uplink and downlink data includes information exchanged via the Internet.
- 10 46. A machine-readable medium as described in claim 33, wherein the smart antenna system includes a plurality of antenna elements and a mechanism for uplink spatial processing signals received at the antenna elements according to a set of receive weighting parameters determined from the signals received at the antenna elements, and a mechanism for downlink spatial processing a signal for transmission according to a set of transmit weighting parameters, wherein the downlink strategy determining step includes determining the set of uplink weighting parameters from the uplink response signal received during the step of receiving the uplink response signal and determining the set of downlink weighting parameters from the set of uplink weighting parameters.
- 15 47. A machine-readable medium as described in claim 33, wherein communication on the downlink channel and on the associated channel is frame-by-frame, and wherein the downlink strategy determining step determines the strategy using the uplink response signal received in the most recent frame.
- 20 48. A machine-readable medium as described in claim 47, wherein the uplink response signal includes acknowledgement data sent by the remote communication device in response to each frame from the first communication device received by the remote communication device.
- 25 49. A machine-readable medium as described in claim 46, wherein the downlink strategy determining step determines the transmit weighting parameters using a blind method and the most recent uplink response signal.

50. A machine-readable medium as described in claim 46, wherein the uplink response signal includes training data and wherein the downlink strategy determining step determines the transmit weighting parameters using the training data in the most recently received uplink response signal.

5 51. A machine-readable medium as described in claim 47, wherein communications on the uplink and downlink channels and on the associated uplink channel are frame-by-frame, and wherein the uplink response signal includes acknowledgement data sent by the remote communication device in response to each frame sent from the first communication device received by the remote communication device, the method further comprising:

10 providing an associated downlink channel from the first communication device to the remote communication device, the associated downlink channel associated with and having a predefined relationship with the uplink channel;

sending an uplink acknowledgement signal from the first communication device to the remote communication device on the associated downlink channel in response to each uplink frame from the user terminal received by the first communication device.

52. A machine-readable medium as described in claim 33, wherein the remote communication device is a user terminal of a set of user terminals able to communicate with the first communication device, each user terminal able to communicate on the uplink on a distinct uplink channel of a set of provided uplink channels and on the downlink on a distinct downlink channel of a set of provided downlink channels, the total data carrying capacity of the set of provided downlink channels being greater than the total data carrying capacity of the set of provided uplink channels,

whereby the method accommodates the asymmetry between uplink and downlink traffic data communication.

25 53. A method of communicating downlink data from a first communication device to a remote communication device, the first communication device including a smart antenna system, the method comprising:

providing a set of sequential time intervals for the first communication device, each of the time intervals having a selected number of downlink channel and the selected number of associated channels on the uplink, each associated uplink channel associated with and having a predefined relationship to one of the downlink channels,

transmitting a downlink polling signal from the first communication device on a first downlink channel of a first time interval;

receiving an uplink response signal at the first communication device from the remote communication device in response to the remote communication device receiving the downlink polling signal, the receiving the uplink response signal being on the associated uplink channel associated with the first downlink conventional channel of the first time interval

determining a downlink smart antenna processing strategy for transmission to the remote communication device using the received first uplink response signal; and

transmitting downlink data from the first communication device to the remote communication device on the first downlink channel using the determined downlink smart antenna processing strategy.

54. A method as described in claim 53, wherein the first communication device includes a base station, the remote communication device includes a user terminal associated with the base station, the smart antenna system includes a plurality of antenna elements, the downlink channel is a downlink traffic channel for communicating downlink traffic data, the sending of the uplink response signal is independent of any uplink traffic data being sent from the remote terminal to the base station, and the downlink smart antenna processing strategy of the sending downlink data step uses a recently received uplink response signal.

55. A method as described in claim 53, wherein the downlink and associated uplink channels are conventional TDMA channels.

56. A method as described in claim 53, wherein the downlink and associated uplink channels are conventional FDMA channels.

57. A method as described in claim 53, wherein the downlink and associated uplink channels are conventional CDMA channels.
58. A method as described in claim 53, wherein the first communication device comprises a cellular base station.
59. A method as described in claim 53, wherein the remote communication device includes a second plurality of antenna elements.
60. A method as described in claim 59, wherein the remote communication device includes a second smart antenna system that includes the second plurality of antenna elements.
61. A method as described in claim 53, wherein the first communication device is coupled to an external data and/or voice network.
62. A method as described in claim 53, wherein the remote communication device includes a remote user terminal.
63. A method as described in claim 62, wherein the remote user terminal is mobile.
64. A method as described in claim 53, wherein at least one of the uplink and downlink data includes voice.
65. A method as described in claim 53, wherein at least one of the uplink and downlink data includes information exchanged via the Internet.
66. A method as described in claim 53,
wherein the downlink polling signal is transmitted during a first time interval of the set and the
downlink traffic data signal is transmitted during a later time interval of the set, and
wherein the downlink data also includes a further downlink polling signal in the later time interval,

the method further including repeating the first uplink response signal transmitting, the receiving and downlink strategy determining, and the downlink data transmitting steps such that downlink communication continues between the first communication device and the remote communication device with subsequent downlink data signals acting as a further downlink polling signal.

67. A method as described in claim 66, wherein the smart antenna system includes a plurality of antenna elements, a mechanism for uplink spatial processing the signals received at the antenna elements according to a set of receive weighting parameters determined from the signals received at the antenna elements, and a mechanism for downlink spatial processing a signal for transmission according to a set of transmit weighting parameters wherein the downlink strategy determining comprises determining the set of uplink weighting parameters from the received first uplink response signal and determining the set of downlink weighting parameters from the set of uplink weighting parameters.

68. A method as described in claim 66, wherein each downlink conventional channel is a distinct downlink data transfer period in each time interval, and wherein each associated conventional channel on the uplink is a distinct data transfer period for uplink communication in each time interval associated with one of the downlink data transfer periods.

69. A method as described in claim 66, wherein the first communication device downlink polling signal transmitted during the first time interval includes downlink data; and

wherein the signal received in the first uplink response signal receiving step includes an acknowledgement to provide feedback to the first communication device of successful reception of the downlink data transmitted during the first time interval.

70. A method as described in claim 66, wherein the transmitting in the downlink data transmitting step is during the next downlink conventional channel of the set that is associated with the associated conventional channel on the uplink for the first uplink response signal transmitting step.

71. A communication device in a communication system, the communication device comprising:

a smart antenna system to communicate with one or more remote communication devices according to a smart antenna processing strategy, the smart antenna system including a plurality of antenna elements;

a downlink transmission unit, coupled to the antenna element plurality, to provide a set of downlink channels, and to transmit downlink data frame-by-frame to a first remote communication devices of the one or more remote communication devices on a first downlink channel of the provided set of downlink channels;

an uplink reception unit, coupled to the antenna element plurality, to provide a set of one or more associated channels on the uplink, each associated channel on the uplink associated, and having a predefined relationship, with one of the set of downlink channels, the set of associated channels including a first associated channel to receive one or more uplink response signals from the first remote user terminal in response to the downlink data and according to a first uplink smart antenna strategy; the uplink reception unit further to provide a set of one or more uplink data channels to receive uplink data frame by frame from one or more of the remote communication devices, the uplink data channels being distinct from the associated channels; and

a processor, coupled to the downlink transmission unit, and further coupled to the uplink reception unit, the processor to determine the first uplink smart antenna strategy and a downlink smart antenna processing strategy based on the received first uplink response signal.

72. A communication device as described in of claim 71, wherein the transmit unit transmits any downlink traffic data frame using a smart antenna processing strategy determined by the processor using the uplink response signal received in the most recent previous frame.

73. A communication device as described in of claim 71, wherein the uplink smart antenna processing strategy includes uplink spatial processing of signals received at the antenna elements according to a set of receive weighting parameters determined from the signals received at the antenna elements, wherein the downlink smart antenna processing strategy includes downlink spatial processing a signal for transmission according to a set of transmit weighting parameters, wherein the processor determines the set of uplink weighting parameters from the received first uplink response signal and determines the set of downlink weighting parameters from the set of uplink weighting parameters.
74. A communication device as described in of claim 71, wherein the total data carrying capacity of the set of provided downlink traffic channels being greater than the total data carrying capacity of the set of provided uplink traffic channels.
75. A communication device as described in of claim 71, wherein the total data carrying capacity of the set of provided downlink traffic channels is the same as the total data carrying capacity of the set of provided uplink traffic channels.
76. A communication device as described in of claim 71, wherein the transmit unit further provides an associated channel on the downlink for each uplink data channel having a predefined relationship to the downlink channel, and wherein the transmit unit further is to transmit an acknowledgement to the first user terminal in response to receiving uplink data on the first uplink traffic channel, the acknowledgment transmitted on the associated channel on the downlink associated with the first uplink traffic channel.
77. A communication device as described in of claim 73, wherein the processor additionally uses one or more uplink response signals received from one or more other co-channel remote communication devices to determine the downlink weighting parameters for transmitting to the first remote communication device such that the determined downlink smart antenna processing strategy includes interference mitigation towards the other co-channel remote communication devices.

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